Determination of Essential Soil Nutrient Levels from Tea Growing Areas in Western and Central Highlands of Kenya

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ABSTRACT

Tea is a vital economic crop in Kenya, especially in the highlands, and is rich in beneficial ingredients like caffeine and polyphenols. Soil nutrients influence the health of tea plants. This study analyzed the levels of Sodium (Na), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Zinc (Zn), Manganese (Mn), Copper (Cu), pH, and moisture content in soil samples from Kisii and Meru Counties. Samples were dried, ground, and digested using aqua regia, with elements analyzed via Atomic Absorption Spectrophotometry and Phosphorus via UV-Vis Spectroscopy. Results for Kisii soil showed higher nutrient concentrations overall, except for Ca, K, and Na, which were higher in Meru. Kisii: Na (8.38 mg/kg), K (36.15 mg/kg), Ca (0.85 mg/kg), Mg (22.075 mg/kg), Mn (14.16 mg/kg), P (0.2765 mg/kg), Cu (2.66 mg/kg), Zn (8.445 mg/kg), MC (22.855%), pH 5.00. Meru: Na (8.69 mg/kg), K (38.6 mg/kg), Ca (0.95 mg/kg), Mg (17.41 mg/kg), Mn (5.675 mg/kg), P (0.236 mg/kg), Cu (0.975 mg/kg), Zn (8.13 mg/kg), MC (27.995%), pH 5.81. Kisii soil had higher overall nutrient levels, with potassium being the highest. Both samples were deficient in Ca and P. The pH levels were suitable for tea production. Mn and Mg levels exceeded World Reference Base (WRB) standards, while Zn, Na, and Cu were within Food and Agriculture Organization (FAO) limits. Ca and P were below WRB and FAO standards.

Keywords: Tea, Kenyan highlands, Soil nutrient levels, Sodium (Na), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), pH, Moisture content, Meru, Kisii

INTRODUCTION

Tea (Camellia sinensis), a small shrub previously known as Theasineusis, is classified into four types: Chinese big tea leaf, Chinese small tea leaf, Shan tea, and Indian tea. Originating from the "Tea Triangle" formed by Naga, Manipur, and Lushai along the borders of Assam and Burma, tea's history also includes origins traced to Vietnam through studies conducted in Burma and Thailand [1]. Today, tea stands as the most widely consumed beverage worldwide, providing significant economic and health benefits.

Kenya is a leading tea producer, with tea serving as a crucial foreign exchange earner for the country. The western and central highlands of Kenya are particularly notable for their prolific tea production, largely attributed to favorable soil and climatic conditions. However, the productivity and quality of tea are highly dependent on soil nutrient levels, which are essential for the healthy growth and development of tea plants.

Optimal nutrient management is crucial for sustainable tea production. Studies have shown that the ideal soil pH for tea cultivation ranges from 4.5 to 5.5, with specific nutrient requirements varying by region and tea variety [2]. For instance, research in China's Zhejiang province found that the optimal levels of soil organic matter, total nitrogen, available phosphorus, and available potassium for high-quality green tea production were 30.7 g/kg, 2.25 g/kg, 33.5 mg/kg, and 136.7 mg/kg, respectively [3]. In India, recommended nutrient levels for tea gardens include 280-350 kg N/ha, 20-30 kg P/ha, and 140-210 kg K/ha annually [4].

Imbalances in these nutrients, whether deficiencies or excesses, can severely impact plant health and productivity [5]. Despite the importance of soil nutrients, there is limited information on their levels in the tea-growing regions of Kenya's western and central highlands. While some studies have assessed nutrient levels in various agricultural areas, specific data for these key tea-producing regions remain scarce. This lack of comprehensive information hinders tea farmers' ability to optimize soil management practices, potentially leading to reduced tea yields and quality [6].

The proposed research project seeks to address this knowledge gap by determining the essential soil nutrient levels in the tea-growing areas of Kenya's western and central highlands. Through systematic soil sampling and laboratory analysis, the project will measure key nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium. The findings will provide valuable insights to tea farmers and policymakers, enabling them to adopt informed soil management practices that enhance tea productivity and quality. Moreover, this study will contribute to the broader knowledge base on soil nutrient levels in Kenya's tea-growing regions and may guide future research in this area.

Statement of the Problem

The tea industry is a cornerstone of Kenya's economy, particularly in the western and central highlands where the climate and soil conditions are ideal for tea cultivation. However, the productivity and quality of tea in these regions are not fully optimized due to a lack of precise information on the essential soil nutrient levels. Soil nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium are critical for the healthy growth and development of tea plants [4]. An imbalance in these nutrients can lead to poor plant health, reduced yields, and lower quality tea leaves.

Currently, the data on soil nutrient levels in the tea-growing areas of Kenya's western and central highlands is insufficient and fragmented. This knowledge gap poses a significant challenge for tea farmers, who need accurate information to manage soil fertility effectively. Without this information, farmers are unable to make informed decisions about fertilization and soil management practices, leading to suboptimal tea production [5].

The absence of comprehensive and localized soil nutrient data limits the potential for maximizing tea yields and quality, ultimately affecting the livelihoods of farmers and the overall economy. To address this issue, it is essential to conduct a detailed study to determine the levels of essential soil nutrients in these key tea-growing regions.

This research aims to fill this critical knowledge gap by providing up-to-date and accurate data on soil nutrient levels. The findings will be crucial for developing effective soil management strategies, ensuring that tea plants receive the necessary nutrients for optimal growth. This, in turn, will help enhance tea production, improve quality, and support the economic stability of the tea industry in Kenya.

General Objective

The general objective is to determine essential soil nutrient levels from tea growing areas in the western and central highlands of Kenya

Specific objectives

The specific objectives of this study are to:

i. Determine the soil physical and chemical parameters (pH and moisture content) levels from three sampling sites in Kisii and Meru Counties.

ii. Determine the primary macro-nutrients nitrogen, phosphorus, and potassium, as well as the secondary macro-nutrients magnesium and calcium levels in soil from three sampling sites in Kisii and Meru Counties.

iii. Determine soil micronutrients sodium, manganese, copper, and zinc levels in soil from three sampling sites in Kisii and Meru Counties.

iv. Compare the nutrient levels in soil samples from the three sites in Kisii and Meru Counties.

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Justification of the Study

This study is crucial for maximizing the potential of tea production in Kenya's western and central highlands, regions that are pivotal to the country's tea industry. Tea farming is a significant economic activity in these areas, providing income for numerous smallholder farmers and contributing substantially to Kenya's foreign exchange earnings [6]. However, the productivity and quality of tea are heavily dependent on the balance of essential soil nutrients, including nitrogen, phosphorus, potassium, calcium, and magnesium. Currently, there is a lack of comprehensive, localized data on soil nutrient levels in these key tea-growing regions.

Understanding soil nutrient levels is fundamental for developing effective soil management strategies. Proper nutrient management can lead to improved tea yields and higher quality leaves, enhancing the economic returns for farmers and bolstering the country's tea exports. Additionally, informed nutrient management practices can prevent the overuse or misuse of fertilizers, promoting sustainable agricultural practices and protecting the environment. This study will fill a critical knowledge gap by providing detailed insights into the nutrient status of soils in the western and central highlands, enabling farmers to optimize their cultivation practices [7].

Furthermore, the findings from this research will serve as a valuable resource for policymakers and agricultural advisors, guiding the development of targeted interventions and support programs aimed at improving soil health and tea productivity. By empowering farmers with precise information on soil nutrient levels, this study will help them make informed decisions, ultimately leading to increased efficiency and sustainability in tea farming.

MATERIALS AND METHODS

Study area

The soil samples that were analyzed for essential nutrients in tea growing areas were obtained from Kisii County and Meru County as shown in figure 1 and figure 2 respectively. Kisii County is one of the forty-seven counties in Kenya lying on the Gusii Highlands of Kenya. It is located between 0.677 S and 34.7790 E and is characterized by rich red volcanic soils and a highland equatorial climate. It is ideal for tea farming carried out in small and large scale [8].

Figure 1: Map of Kisii County shows the location of the sample.

Meru County is one of the counties in Kenya. It is located in the Eastern Highlands of Kenya. It is located between 0.622 N and 37.6502 E. The County is characterized with a highland equatorial climate and rich volcanic soils that are ideal for tea farming [9].

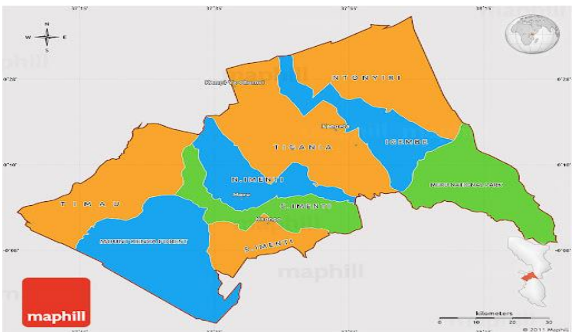

Figure 2: Map of Meru County showing the location of sample collection.

In Meru County, three soil samples were collected by first selecting three distinct locations: a coffee farm, a maize field, and a forested area. At each site, a soil probe was used to extract samples from the top 8 inches of soil. The soil samples were collected from a depth of 8 inches (20 cm). This depth was chosen because it represents the typical rooting zone for tea plants. While tea roots can extend deeper, the majority of active nutrient uptake occurs in the top 15-30 cm of soil [10]. Sampling at this depth provides a representative assessment of the nutrient status in the most crucial zone for tea plant nutrition. Subsamples were taken in a zigzag pattern across each location, combined into composite samples, and stored in labeled bags. In Kisii County, the process was replicated in a tea plantation, a vegetable garden, and a banana plantation. Using the same method, soil probes were inserted to a depth of 8 inches, subsamples were mixed from various points within each site, and the composite samples were labeled and transported to the analytical laboratory in the Department of Chemistry at the University of Nairobi, for analysis.

Reagents and apparatus

The reagents used include, the reagents and standards for Zn, Mn, Cu, Mg, Na, K and Ca were manufactured by Sigma-Aldrich Company, USA.

The apparatus that was used include the Atomic Absorption Spectrometry (AAS), UV-VIS Spectrophotometer analytical balance (C054-E032Q Shimadzu), pH-EC-TDS meter (HANNA 9812), mechanical/orbital shaker, extraction bottle with stopper, laboratory glassware and sampling bottles.

Sample Preparation

The soil samples were sieved to remove debris and then were dried in the oven at 105^{o}C, all the soil samples were thoroughly mixed to create composite and homogeneous samples. Digestion was conducted at 330°C for two hours in a fume chamber. After cooling for 20 minutes, 25 ml of distilled water was added. The mixture was then decanted into storage bottles for further analysis.

pH determination

The pH was determined using HANNA 9812 pH meter calibrated using buffer solutions of pH 4, 7 and 10. All the readings were taken at room temperature.

The soil pH was determined by taking 20 g of each homogenized sieved sample in a 100 mL beaker then adding 50 mL of deionized water to form a 2:5 soil-water suspension. The mixture was mechanically shaken at 15 rpm for 15 minutes using an orbital shaker before the electrode was immersed into the suspension to determine the pH. The reading was taken after 30 minutes. This method follows the standard procedure described by Thomas (1996) [11].

Percentage moisture content determination

The moisture content in this study was determined using the oven-drying method. Samples were dried overnight in an oven at 105°C. Each sample was analyzed in triplicates. For each analysis, 2 grams of the sample was measured. According to a referenced study [10], the following formula was used to determine the moisture content of the samples:

Moisture content =

$$\frac{(\text{Initial weight - Oven-dried weight})}{\text{initial weight}} \times 100$$

Atomic Absorption Spectrometry

The calibration was done by introducing de-ionized water as blank to adjust the reading of the instrument. The standard working solutions of metals Zn, Mn, Cu, Mg, Na, K and Ca that had been prepared were analyzed using different wavelength. After calibration, each sample was introduced into the instrument as shown in figure 3 and the readings obtained were recorded. The analysis of metals (Zn, Mn, Cu, Mg, Na, K, and Ca) using AAS followed the methods described by Sparks et al. (1996) [12].

Figure 3: Atomic Absorption Spectrometry instrument used for analysis.

UV -VIS Spectrophotometry

UV-VIS spectroscopy analyzes how molecules absorb ultraviolet (UV) and visible (VIS) light as depicted Figure 4, and was used to determine phosphate levels in the soil samples. It operates by projecting light through a sample while measuring how much light is reflected or absorbed. The resulting spectrum offers data on the concentration and electronic structure of the material. The determination of phosphate levels using UV-VIS spectrophotometry was conducted following the ascorbic acid method as described by Murphy and Riley (1962) [13].

Figure 4: UV-VIS Spectronic spectrophotometer for phosphate determination.

Statistical data analysis

The analysis of data obtained was carried out using Microsoft excel, Statistical package for social Science tool (SPSS). Correlation between the sites. The results obtained are presented by use of graphs, statistical tables and text to show the interrelationships of various variables

RESULTS AND DISCUSSIONS

Physicochemical parameters

The physicochemical parameters analyzed in this study are pH and moisture content of the soil samples. The results obtained are presented in Table 1.

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Table 1: The physicochemical parameters of soil samples from Kisii and Meru Counties.

Kisii		
Site/parameter	pH	% Moisture content (mg/kg)
1	5.00 ± 0.01	22.83± 0.02
2	5.10±0.03	22.88± 0.01
3	5.21±0.01	22.51 ± 0.03
Meru		
1	5.81±0.03	27.94± 0.03
2	5.62±0.02	28.05± 0.01
3	5.74±0.03	28.16 ± 0.03
Recommended levels (mg/kg)		
FAO	4.5-5.0	60-80
WRB	5.0-5.5	60-80

pH levels

The Kisii soil pH levels ranged from 5.00 ± 0.01 -5.21±0.01 while the value for Meru was 5.62±0.02-5.81±0.03 as shown in Table 1. Sites 1 and 2 had the lowest levels of 5.00 ± 0.01 and 5.00 ± 0.01 in Kisii and Meru respectively. The pH levels of soil were higher in the Meru than Kisii as shown in figure 5.

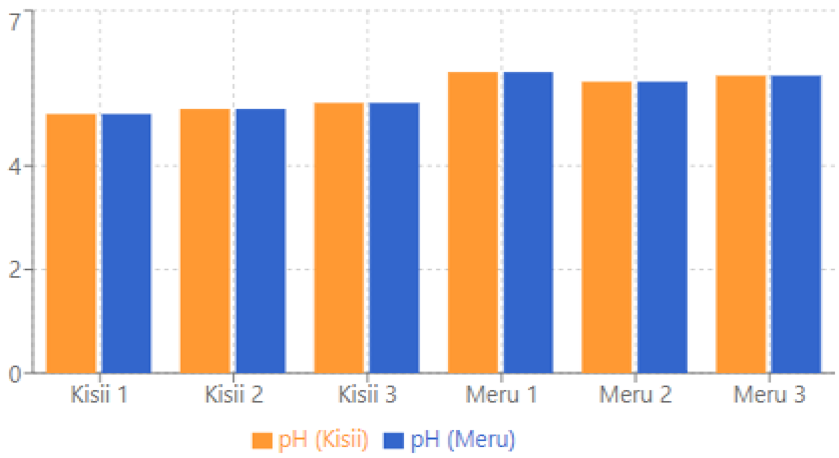

Figure 5: pH levels in soil samples.

The difference in soil pH between the two tea-growing regions can be attributed to various factors, including parent material, climate, and management practices. While climate does influence soil pH, the relationship between rainfall and soil acidity is complex. In high-rainfall areas, such as parts of Kenya, leaching of basic cations can lead to soil acidification over time [14]. The lower pH observed in Kisii samples may result from several factors, including higher rainfall, which increases leaching; different parent materials with varying buffering capacities; intensive farming practices and fertilizer use; and differences in natural vegetation that influence organic matter decomposition [15]. Tillage can also affect soil pH, but its impact is not as straightforward. Tillage can influence pH by mixing soil layers with different pH levels, accelerating the decomposition of organic matter—which releases organic acids—and affecting soil moisture and aeration, thereby influencing microbial activity and nutrient cycling [16]. The differences in soil pH between the two regions can significantly impact the growth and quality of tea produced, as tea plants prefer slightly acidic soils, typically in the range of 4.5 to 5.5 pH, where most essential nutrients are readily available for uptake [17].

Percentage moisture content

The Kisii soil percentage moisture content levels ranged from 22.51 ± 0.01-22.88± 0.01 mg/kg while the value for Meru was 27.94± 0.03-28.16 ± 0.03mg/kg as shown in Table 2. Sites 3 and 1 had the lowest levels of 22.51± 0.01 % and 27.94± 0.03 % in Kisii and Meru respectively. The soil percentage moisture content levels were higher in Meru than Kisii County as depicted in Figure 6

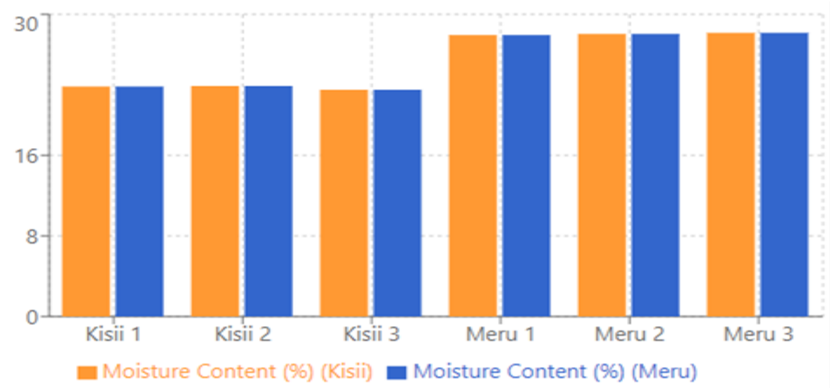

Figure 6: Percentage moisture content levels in soil samples.

Soil moisture content plays a crucial role in both the quality and quantity of tea production. Adequate soil moisture is essential for nutrient uptake, photosynthesis, and overall plant health, with the ideal moisture content for tea cultivation typically ranging from 60 to 80% of field capacity [17]. The importance of soil moisture for tea production can be highlighted through several key factors. First, proper soil moisture facilitates the movement of nutrients in the soil solution, making them accessible to tea plant root. Additionally, adequate moisture supports cell expansion, leading to larger, higher-quality tea leaves. Sufficient water is also crucial for maintaining optimal photosynthetic rates, which directly impacts tea yield. Furthermore, well-hydrated plants exhibit greater resilience to environmental stresses, including pests and diseases. Finally, soil moisture status can influence the production of various flavor compounds in tea leaves, affecting the final product quality [15]. However, the observed moisture content levels in both Kisii (22.51-22.88%) and Meru (27.94-28.16%) samples are below the optimal range for tea cultivation. This suggests that irrigation or water conservation practices may be necessary to improve tea productivity and quality in these regions.

Soil essential elements

The soil essential elements that were analyzed in this study include; Na, Ca, Mg, P, Cu and Zn. The results are as shown in Table 2

Table 2: Essential elements metal levels in soil from Kisii and Meru Counties tea farms

Kisii County								
Site/Element	Na (mg/ kg)	K (mg/ kg)	Ca (mg/ kg)	Mn (mg/ kg)	Mg (mg/ kg)	P (mg/kg)	Cu (mg/ kg)	Zn(mg/kg)
1	6.72±0.21	36.1±0.57	1.50±0.07	15.29±0.22	22.1±0.33	0.198±0.04	2.73±0.01	8.06±0.26
2	5.46±0.22	36.2±0.56	0.90±0.08	14.29±0.23	25.34±0.32	0.252±0.003	3.41±0.03	8.83±0.27
3	8.30±0.23	33.9±0.58	0.80±0.06	14.03±0.021	22.01±0.34	22.01±0.005	2.59±0.03	7.51±0.26
Meru County								
1	7.48±0.11	30.10±0.07	1.00±0.07	5.52±0.018	17.64±0.09	0.176±0.03	0.770±0.10	7.37±0.54
2	8.84±0.14	38.2±0.05	2.80±0.08	5.15±0.014	17.18±0.09	0.233±0.05	0.98±0.20	7.94±0.58

3	8.54±0.12	39.0±0.08	0.90±0.06	5.83±0.017	20.14±0.09	0.239±0.03	0.97±0.4	8.32±0.60
Recommended levels								
FAO (mg/kg)	0.5-5	0.5-5	0.05-5	20-200	20-200	0.1-5	2-20	10-100
WRB (m/kg)	20-30	20-30	120-140	50-100	30-60	3-5	25-10	25-50

Sodium levels

The concentration levels of sodium in the Kisii soil samples ranged from 5.46±0.22- 8.30±0.23 mg/kg, while for the Meru were 7.48±0.11-8.84±0.14 mg/kg. The Na levels were all higher than the stipulated levels of (0.5-5mg/kg) by WRB (2014). Sampling sites 3 and 2 had the highest levels of 8.54±0.12 and 8.84±0.14 sodium in Kisii and Meru County respectively shown Table 2. In both the Counties Sites 2 and 1 had the lowest levels of sodium respectively as shown in Figure 7

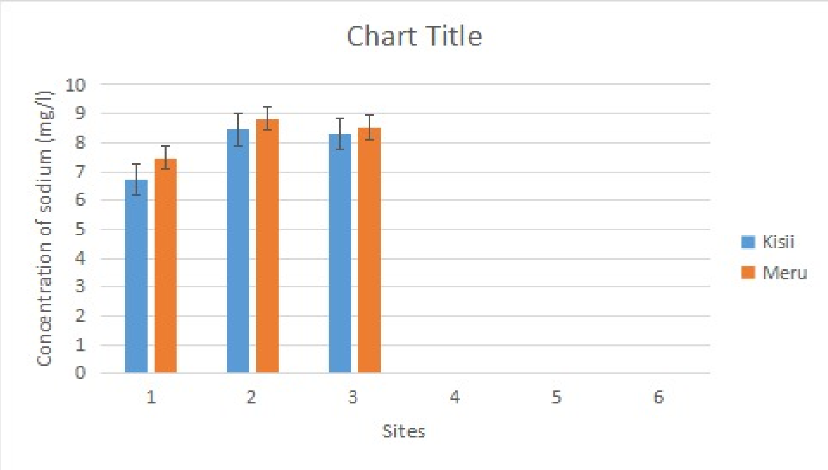

Figure 7: Sodium concentration in the sampling sites

Potassium

The concentration of K in the Kisii soil samples was 36.1mg/kg, 36.2mg/kg and 33.9mg/kg respectively. The concentration levels for the Meru soil samples were 30.1mg/kg, 38.2mg/kg and 39mg/kg respectively. The K concentration levels were higher than the stipulated levels of (0.5-5 mg/kg) by FAO. Sampling site 2 had the highest K concentration while sampling site 3 had the lowest concentration levels for the Kisii soil samples as shown in table 2. Sampling site 3 had the highest K concentration while sampling site 1 had the lowest concentration levels for the Meru soil samples as shown in figure 8.

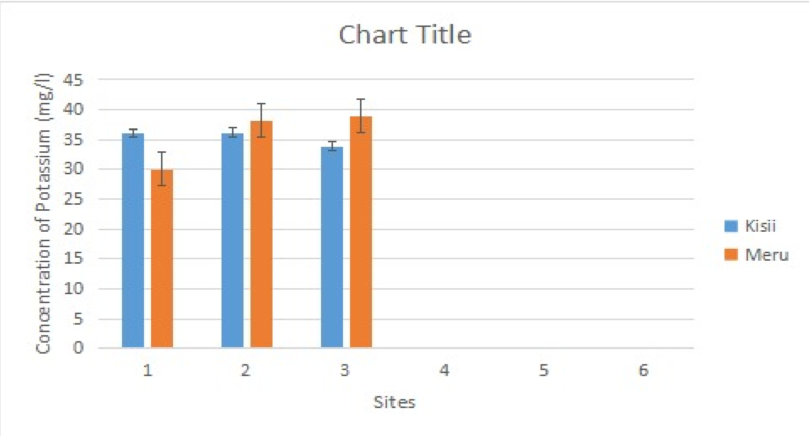

Figure 8: Potassium concentration in the sampling sites

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Calcium

In this research, Ca concentrations in Kisii soil samples were 1.5mg/kg, 0.9mg/kg and 0.8mg/kg respectively. For the Meru soil samples the concentrations were 1.0mg/kg, 2.8mg/kg and 0.9mg/kg respectively. These concentrations were within the stipulated levels of (0.05-5mg/kg) by FAO. Sampling site 1 had the highest concentration of Ca while sampling site 3 had the lowest concentration in the Kisii soil samples as shown in Figure 9, Sampling site 2 had the highest concentration of Ca while sampling site 3 had the lowest concentration in the Meru soil samples.

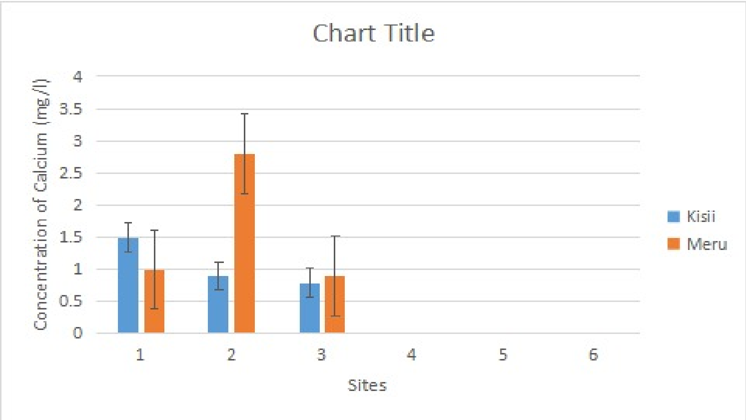

Figure 9 Calcium concentration in the sampling sites

Magnesium

The Mg concentration levels in the Kisii soil samples were 22.14mg/kg, 25.34mg/kg and 22.01mg/kg respectively. The Meru soil samples the concentration levels were 17.64mg/kg, 17.18mg/kg and 20.14mg/kg respectively. The Mg concentration levels were higher than the stipulated levels of (0.1-1mg/kg) by FAO. Sampling site 2 had the highest Mg concentration levels while sampling site 3 had the lowest concentration levels in the Kisii soil samples as shown in Figure 10. For the Meru soil samples, sampling site 3 had the highest Mg concentration levels while sampling site 2 had the lowest concentration levels.

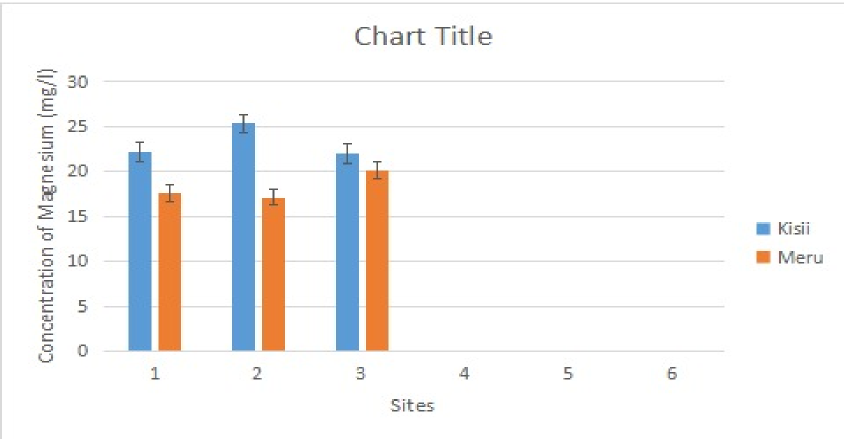

Figure 10: Magnesium concentration in the sampling sites

Manganese

Concentration levels of Mn in the Kisii soil samples were 15.29mg/kg, 14.29mg/kg and 14.03mg/kg respectively. The Meru soil samples the Mn concentration levels were 5.52mg/kg, 5.15mg/kg and 5.83mg/kg respectively. The Mn concentration levels were below the stipulated levels of (20-200mg/kg) by FAO. Sampling site 1 had the highest Mn concentration levels while sampling site 3 had the lowest concentration levels in the Kisii soil samples as shown in Figure 11. For the Meru soil samples, sampling site 3 had the highest Mn concentration levels while sampling site 2 had the lowest concentration levels.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume IX Issue IX September 2024

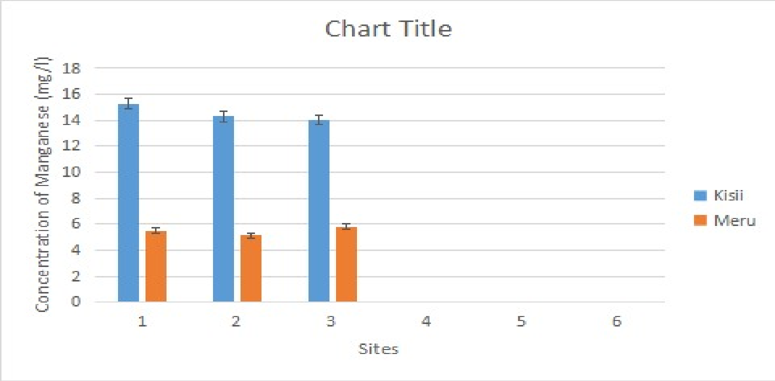

Figure 11: Manganese concentration in the sampling sites

Phosphorus

In this study, P concentration levels in Kisii soil samples were 0.198mg/kg, 0.252mg/kg and 0.301mg/kg respectively. The Meru soil samples the concentration levels were 0.176mg/kg, 0.233mg/kg and 0.239mg/kg respectively. These concentrations levels were within the stipulated levels of (0.1-5mg/kg) by FAO. Sampling site 3 had the highest P concentration levels while sampling site 1 had the lowest concentration levels in the Kisii soil samples as shown in Figure 12, Meru soil samples, sampling site 3 had the highest P concentration levels while sampling site 1 had the lowest concentration levels.

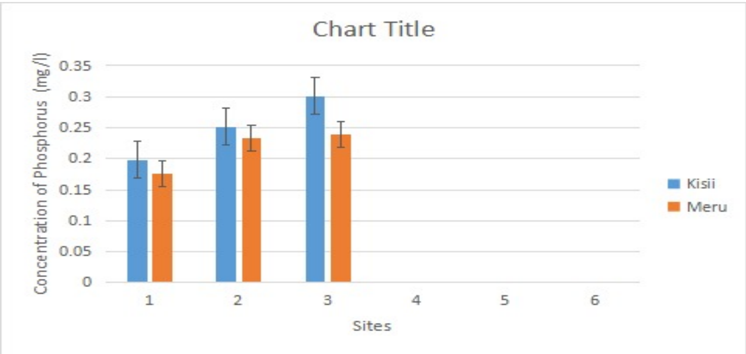

Figure 12: Phosphorus concentration in the sampling sites

Copper

The Cu concentration levels in the Kisii soil samples were 2.73mg/kg, 3.41mg/kg and 2.59mg/kg respectively. The Meru soil samples, the concentration levels were 0.77mg/kg, 0.98mgk/g and 0.98mg/kg respectively. The concentration levels were within the stipulated levels of (2-20mg/kg) by FAO. Sampling site 2 had the highest Cu concentration levels while sampling site 3 had the lowest concentration levels in the Kisii soil samples as shown in Figure 13, Meru soil samples, sampling site 2 and 3 had the highest Cu concentration levels while sampling site 1 had the lowest concentration levels.

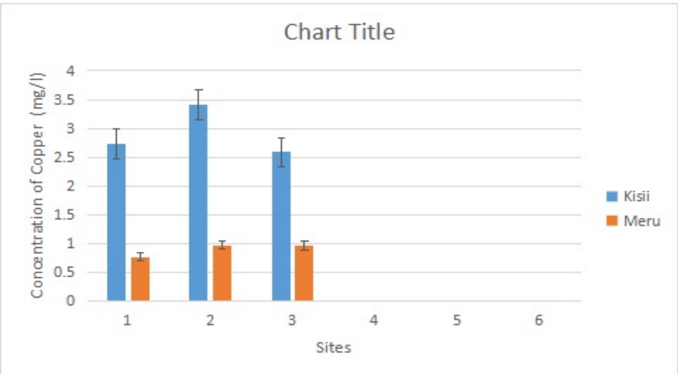

Figure 13: Copper concentration in the sampling sites

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Zinc

Concentration levels of Zn in Kisii soil samples were 8.06mg/kg, 8.83mg/kg and 7.51mg/kg respectively. The Meru soil samples the concentration levels were 7.37mg/kg, 7.94mg/kg and 8.32mg/kg respectively.The Zinc concentration levels were below the stipulated levels of (10-100mg/kg) by FAO. Sampling site 2 had the highest Zn concentration levels while sampling site 3 had the lowest concentration levels in the Kisii soil samples as shown in Figure 14, Meru soil samples, sampling site 3 had the highest Zn concentration levels while sampling site 1 had the lowest concentration levels.

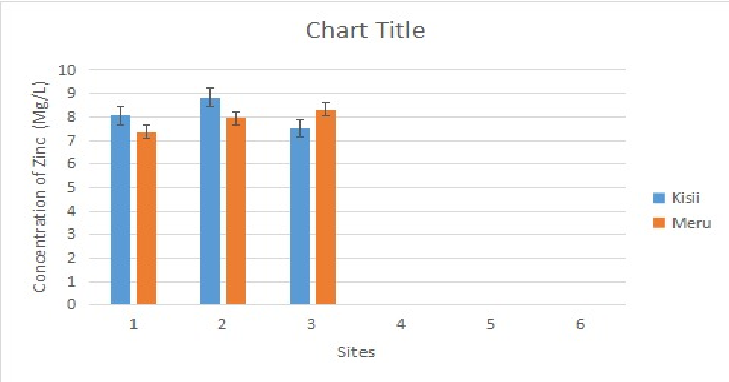

Figure 14: Zinc concentration in the sampling sites

In both soil samples Potassium recorded the highest concentration while Phosphorus recorded the lowest concentration, K>Mg>Mn>Zn>Na>Cu>Ca>P.

Meru soil sample had the highest amount of Potassium and the lowest level of Phosphorus compared to the Kisii soil sample. The soils are moderately acidic. Potassium S odium and Magnesium are supplied in excess in the soil. Calcium, Copper and Phosphorus are marginally supplied in the soil. Zinc and Manganese are deficient in the soil.

The readings of each standard solution were recorded, and the correlation coefficient and a regression equation were calculated using M.S. Excel. Correlation values range from +1 to -1, where a value of 1 shows a perfect positive correlation, -1 indicates a perfect negative correlation, and 0 indicates no linear relationship exists. The r^2 values in the results were within the linear range hence a positive correlation. With regression equations of (y=0.0076x+0.3056), (y=0.0058x+0.0599), (y=0.164x-0.066), (y=0.0249x+0.0729) Magnesium, Calcium, Phosphorus and Sodium had the highest correlation coefficient (r^2=1). Zinc had the lowest correlation (r^2= 0.9701). The r^2 values for other trace elements were as shown in the table 3.

Table 3: Correlation Coefficient of the Essential Trace Elements

Parameter	**Instrument**	**r 2**	**Regression equation**
Ca	AAS	1	y=0.0058x+0.0599
P	Uv-vis	1	y=0.164x-0.066
Mg	AAS	1	y=0.0076x+0.3056
Mn	AAS	0.9994	y=0.0227x+0.0197
K	AAS	0.9999	y=0.0006x-0.0005
Cu	AAS	0.9996	y=0.0288x+0.0258
Na	AAS	1	y=0.0249x+0.0729
Zn	AAS	0.9701	y=0.0156x+0.1779

CONCLUSIONS

Tea is an important source of polyphenols, alkaloids and caffeine which have good health effects such as anti-oxidant and reduced risk of cardiovascular disease.

The study indicated that the soil samples contained more Potassium compared to other elements .The potassium concentration levels (38.6± 0.5657-36.15± 0.0707 mg/kg) were higher than the stipulated levels of (0.5-5 mg/kg) by FAO (2006), Magnesium concentration levels (17.41± 0.3253 -22.075± 0.09192 mg/kg) and were higher than the stipulated levels of (0.1-1mg/kg) by FAO, Sodium concentration levels (8.69 ± 0.2121 -8.38± 0.1131 mg/kg) and were higher than the stipulated levels of (0.5-5mg/kg) by WRB[11], The Phosphorus concentration levels (0.236± 0.004243 -0.2765± 0.03465 mg/kg) and were within the stipulated levels of (0.1-5mg/kg) by FAO, Calcium concentration levels (0.95± 0.0707 -0.85± 0.0707 mg/kg) and were within the stipulated levels of (0.05-5mg/kg) by FAO, Copper concentration levels (0.975± 0.007071-2.66± 0.09890 mg/kg) and were within the stipulated levels of (2-20mg/kg) by FAO, Zinc concentration levels (8.13± 0.2687 -8.445± 0.5445 mg/kg) and were below the stipulated levels of (10-100mg/kg) by FAO, Manganese concentration levels (5.675± 0.2192 -14.16± 0.1838 mg/kg) and were below the stipulated levels of (20-200mg/kg) by FAO[12].

The moisture content recorded from the soil samples were as follows: Meru (sample i-27.94%, sample ii-28.05% and sample iii-28.16%), Kisii (sample i-22.83%, sample ii-22.88% and sample iii-22.51%).

The variations in the moisture content could be due to sample collection from different levels in each of the study regions.

RECOMMENDATION

In recent years, the quality of tea production has faced challenges that could be mitigated through better education of farmers on the importance of soil nutrients for optimal tea leaf quality and quantity. Based on the findings of this study, several recommendations have been formulated. Firstly, farmers are advised to prepare planting holes a week prior to transplanting, filling each with a mixture of topsoil, 1.5 kg of well-decomposed farmyard or compost manure, and 300g of N:P fertilizer (preferably 17:17:17). Once the crops have established themselves, typically after six to eight months, it is recommended to top-dress with Calcium Ammonium Nitrate (CAN) at a rate of 350g per plant or stem, ensuring the soil is adequately moist during application to support emerging stems. Depending on the crop's condition, foliar or granular N.P.K fertilizers can be applied during flowering or early fruiting stages. In subsequent years, increasing amounts of manure and fertilizer should be applied to sustain stem growth and improve crop yields. Moreover, maintaining well-drained, adequately moist soil and implementing effective pest and disease management strategies are crucial for sustaining healthy tea crops and enhancing overall production quality.

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